

STRUCTURE FORMATION of LIQUID CRYSTALLINE POLYMERS IN WEAK SHEAR LIMIT

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One of the confounding issues in laminar flow processing of nematic polymers is the generation of molecular orientational structures on lengthscales that remain poorly characterized with respect to molecular and processing control parameters. For plane Couette flow within the Leslie-Ericksen (L-E) continuum model, a series of theoretical results for nematic director structures were obtained: exact steady solutions (Manneville, Carlsson), dimensional analysis (deGennes, Marrucci, Marrucci & Greco), and approximate solutions in limiting regimes (Cladis & Torza, Carlsson, Marrucci & Greco, Larson). This body of work conveys two fundamental predictions: a power law scaling behavior, Er^{-p} , $\frac{1}{4} \leq p \leq 1$, where Er is the Ericksen number (ratio of viscous to elastic stresses) in the lengthscales of director distortion; the exponent p varies according to whether the structure is a localized boundary layer or an extended structure. These scalings penetrate the scale of molecular elasticity, which the L-E theory does not resolve. Until now, comparable results have not been derived for mesoscopic Doi-Marrucci-Greco tensor models, which is the purpose of this paper. We describe one-dimensional gap structures, along the flow-gradient direction y , in Couette cells, which reflect the coupling between flow, director (nematic) & order parameter (molecular) elasticity, as well as confinement conditions on plate speeds, gap height (h), and director anchoring angle (ψ_0). We develop a nonlinear asymptotic analysis in the slow-plate (small Deborah number) limit, which yields exact, steady, flow-nematic structures, from which we read off the mesoscopic predictions.

We close with direct numerical simulations of the DMG steady, flow-nematic boundary-value problem. First, we benchmark the small Deborah number predictions, and then document thresholds for breakdown of the asymptotic formulas. Two types of nonlinear velocity profiles are resonated as De or $De \cdot Er$ grow to order unity: tangential anchoring yields stronger flow gradients near the plates and mid-gap stagnated flow, whereas all other anchoring conditions reverse concavity of the flow profile, promoting plate layers moving at nearly constant plate speed, and a mid-gap layer with large, nearly constant flow gradient. These flow scales correlate with order parameter structures, whereas the director acquires an amplified permeation mode. First (N_1) and second (N_2) normal stress differences inherit plate boundary layers, leading to one (in the asymptotic regime) or more sign changes in N_1 and N_2 .